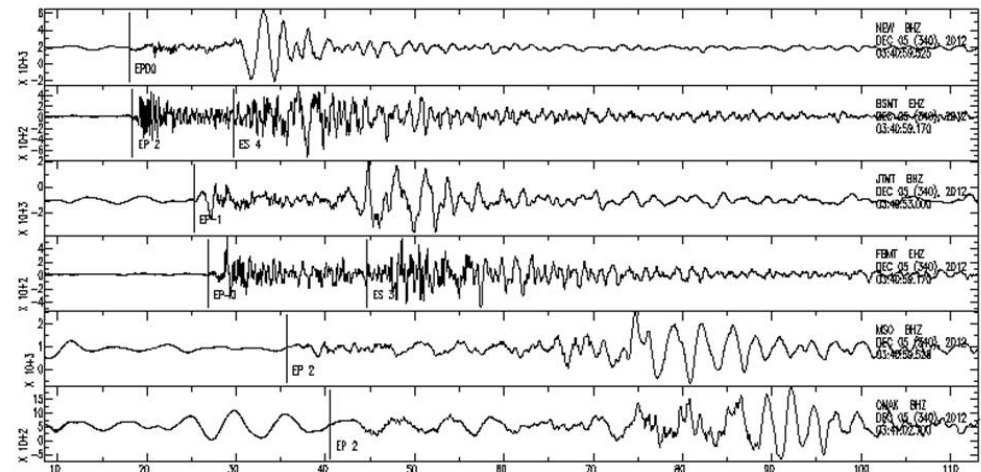


An aerial photograph of the Troy Mine processing plant. The plant consists of several large, light-colored industrial buildings with gabled roofs, situated on a hillside. A dirt road winds through the forest towards the plant. In the foreground, there is a large, long, light-colored metal building with a flat roof, surrounded by various pieces of yellow and blue heavy machinery, including excavators and trucks. The entire site is surrounded by a dense forest of tall evergreen trees.

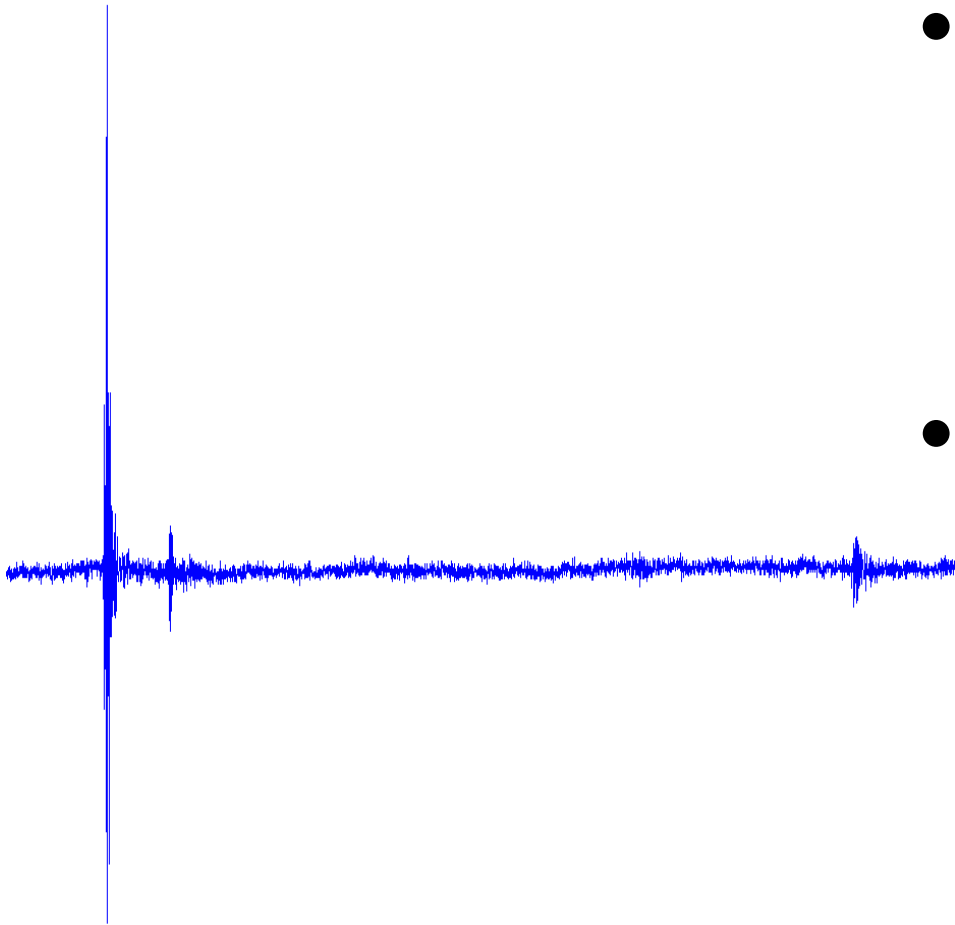
MICROSEISMIC MONITORING AT THE TROY MINE

BRYAN FARBRIDGE
APRIL 2014

- Background
- December 2012 events
- MBMG – Regional seismic monitoring
- NIOSH instrumentation
- ESG geophones
- System expansion



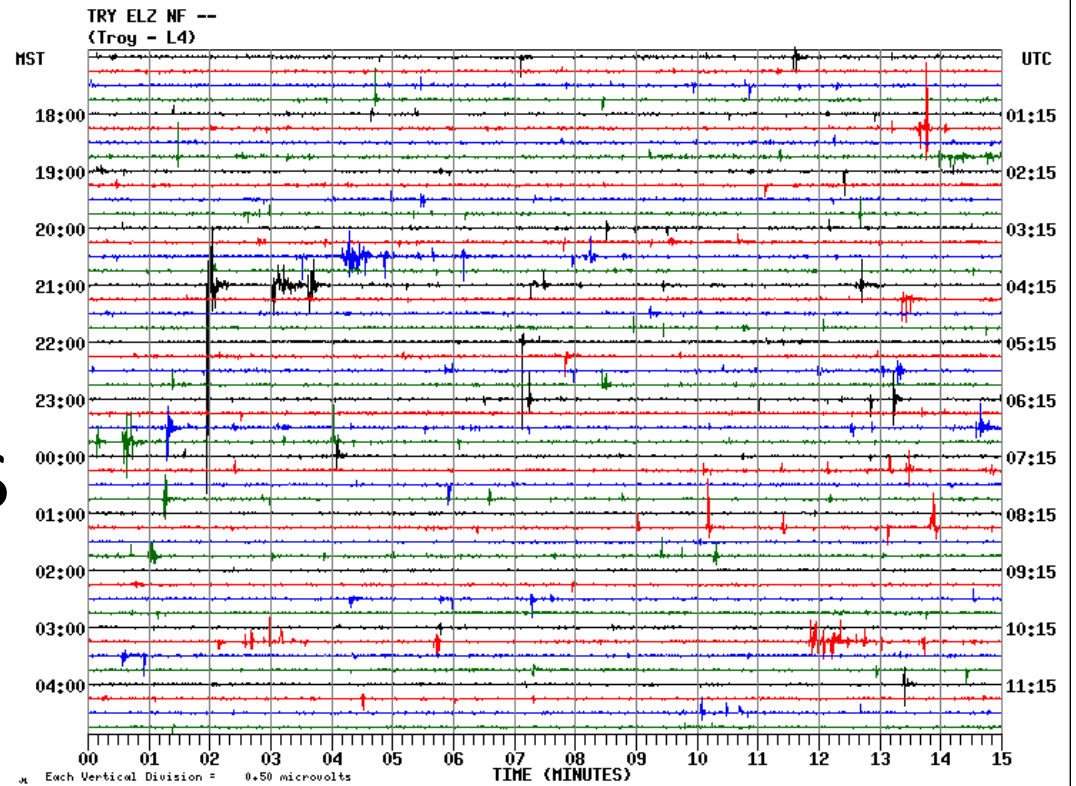
- What is a seismic event?
 - Sudden release of energy within the earth's crust which creates seismic waves, i.e. earthquakes
- What is a microseismic event?
 - Very small scale seismic event commonly heard by miners working underground



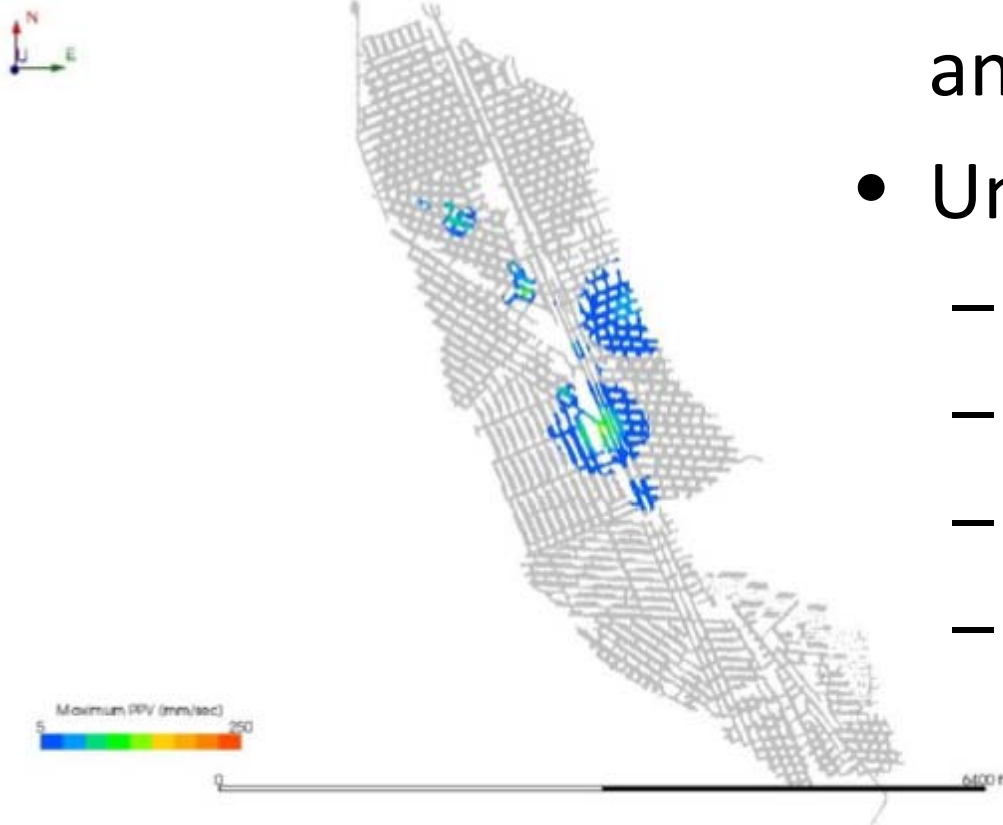


HISTORY OF MINE SEISMICITY

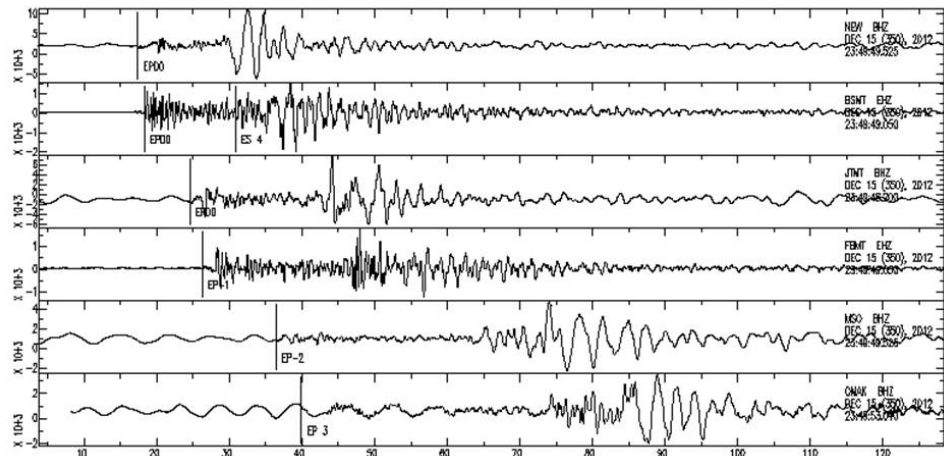
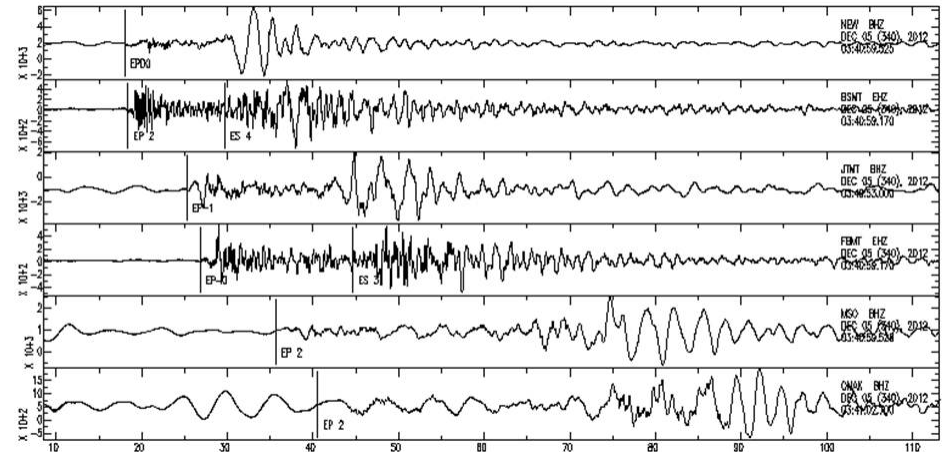
- Rock noise has long been seen as a warning of changing or unstable ground conditions
- Researched by the US Bureau of Mines beginning in the 1930's



- Range of applications including mining, oil & gas, and exploration
- Underground applications:
 - Geotechnical analysis
 - Seismic hazard
 - Rock burst monitoring
 - Peak particle velocity / acceleration
 - Block cave mapping



- Increased rock noise reported by miners
- Suspend operations, begin monitoring audible noise from safe locations
- Events recorded by MBMG

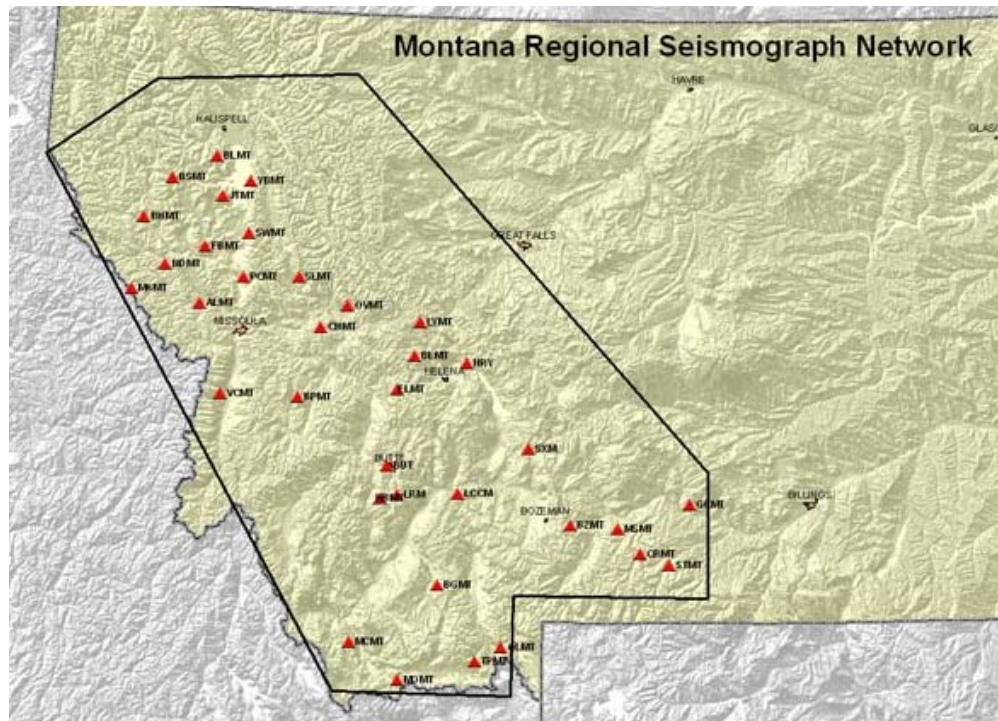


REVETT

Troy Mine Inc.



REGIONAL SEISMIC MONITORING



- Maintained by the Montana Bureau of Mines & Geology
- Confirm on-site observations
- Detect large events
- Limited number of stations in Northwest Montana



ON-SITE INSTRUMENTATION

- Increased seismic activity prevented personnel from going underground
- The decision was made to install a microseismic monitoring system





NIOSH INSTRUMENTATION

- Dr. Pete Swanson installed two seismographs on Dec 21, 2012
- Decreasing trend over the following weeks
- Quantitative measurement of microseismic activity levels within the mine
- Initial estimate of effected areas and seismic velocity

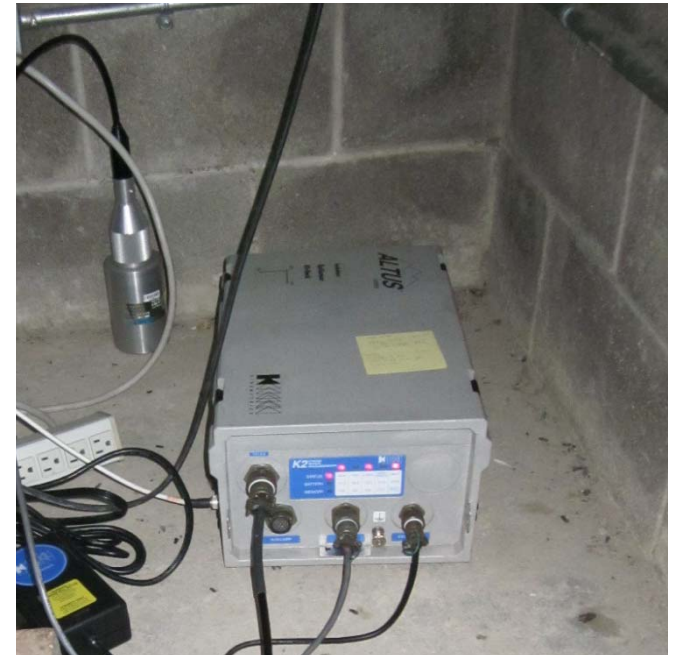
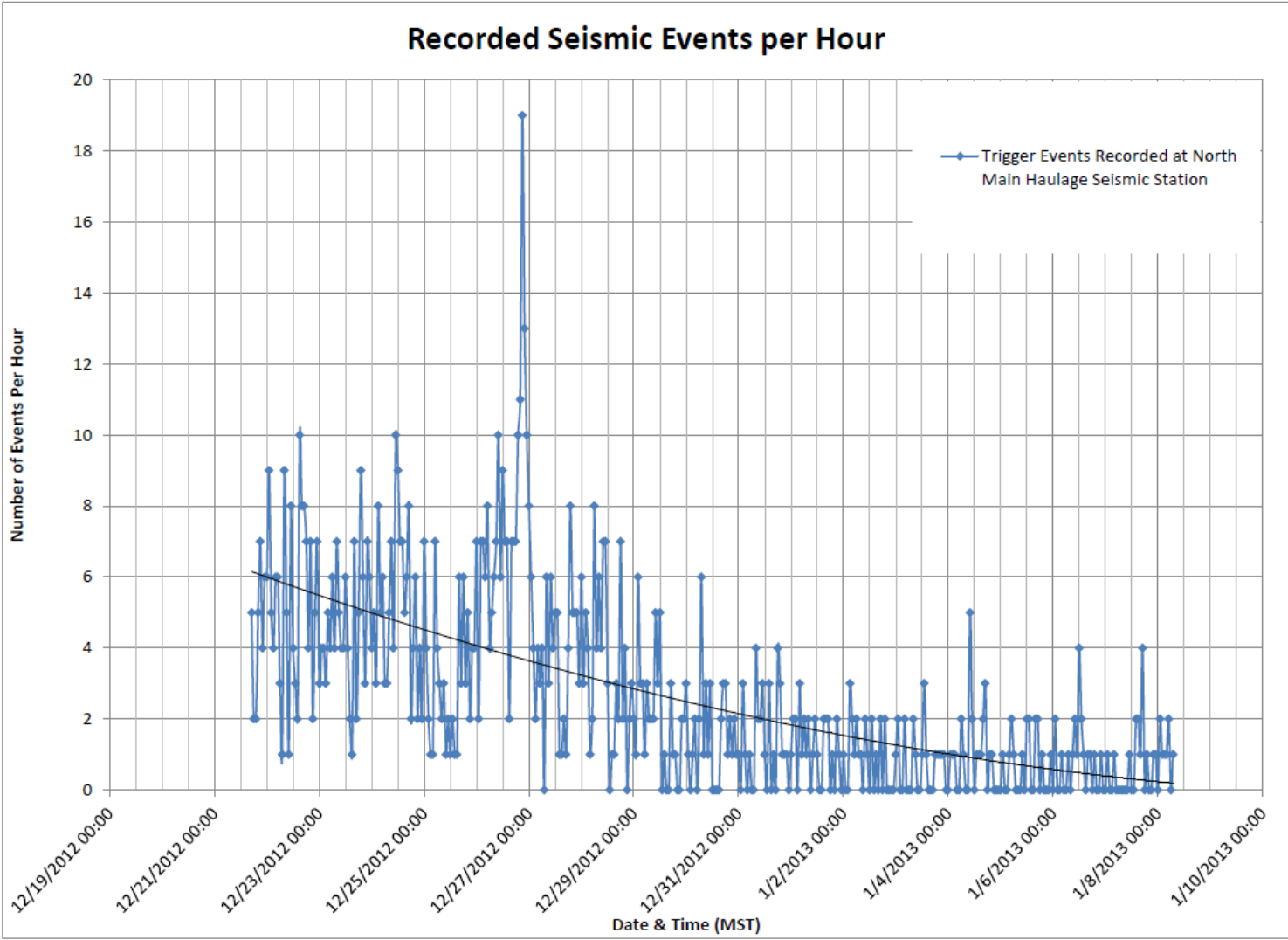


Photo by Dr. Pete Swanson



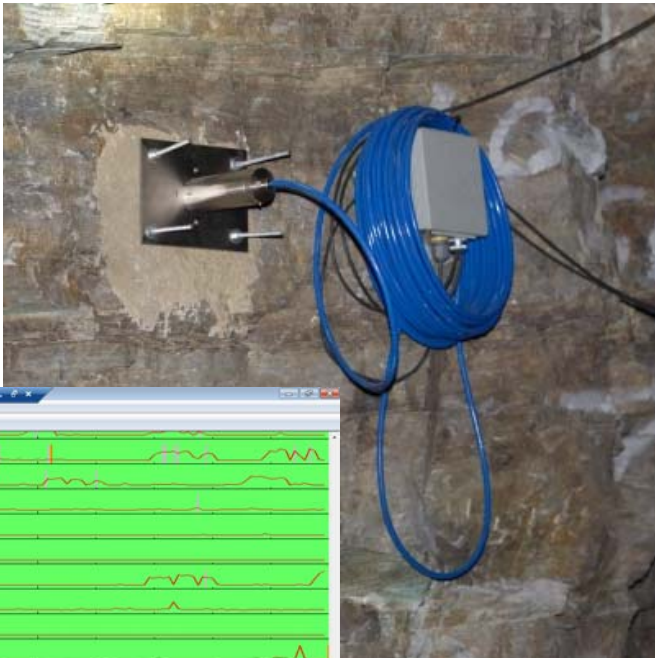
NIOSH INSTRUMENTATION



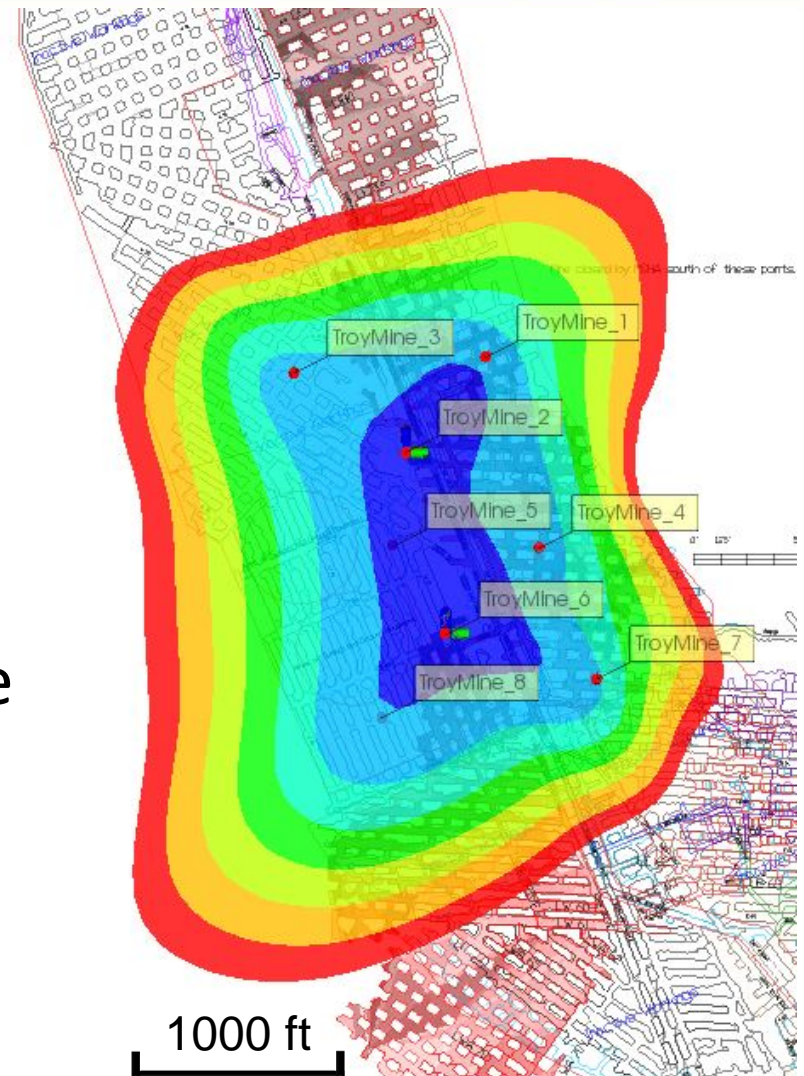


ESG GEOPHONES

- Data Acquisition
 - Sensors
 - Paladin
 - Telemetry
 - HNAS



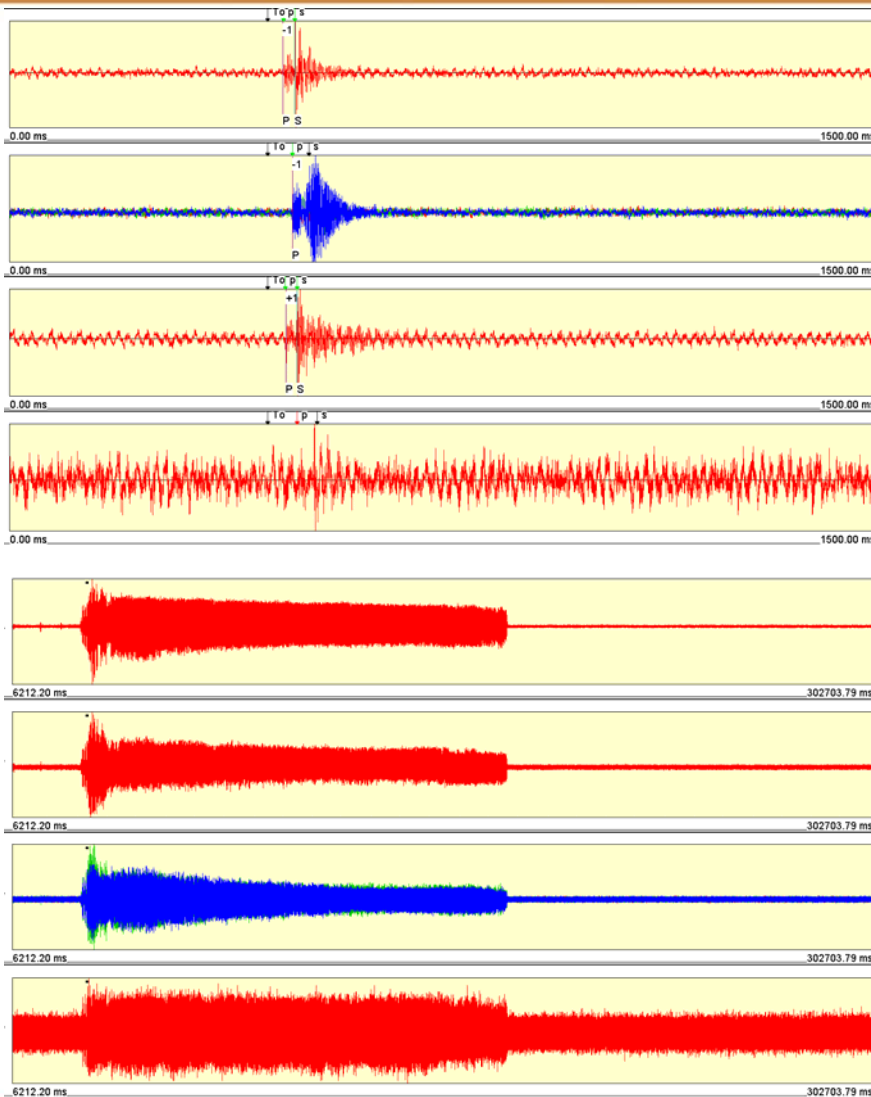
- Determine area of interest
- Work with ESG to optimize array design
 - Sensor spacing
 - Try to surround area of interest with a 3D array of sensors
 - Limited by location of mine workings
 - Determine route from geophones to surface



GEOPHONE INSTALLATION

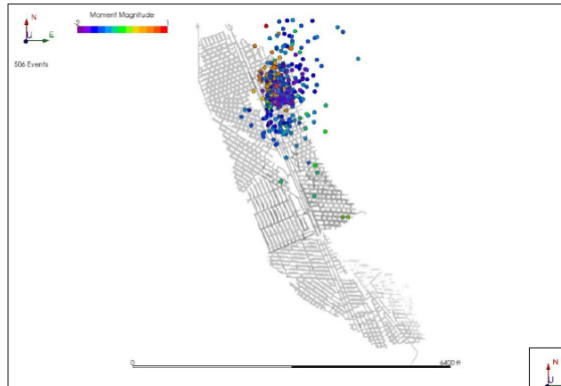


- Finding a safe location for sensors
- 120V power required at each paladin
- Set-up
 - ESG field technician available to provide training and assist with installation
 - Determine triggering parameters



- Event Triggering
 - What constitutes an “event”
- Trigger Parameters
 - Amplitude threshold triggering
 - Number of sensors
 - STA/LTA triggering

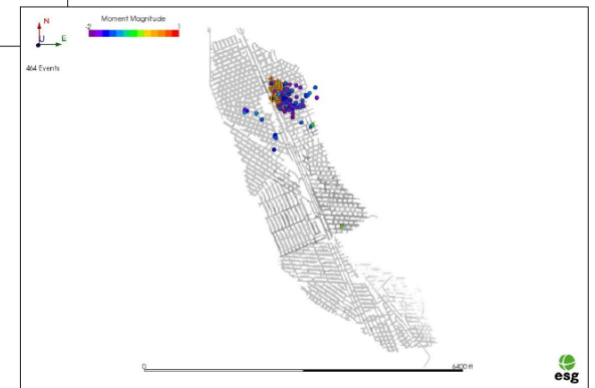
- Defines the event
 - When
 - Where
 - Magnitude
- Dependent on seismic velocity
 - Requires initial calibration blasts
- Automatic vs Manual



- Plan view of automatically processed seismic event/blast/noise locations

- Plan view of manually processed seismic event/blast/noise locations

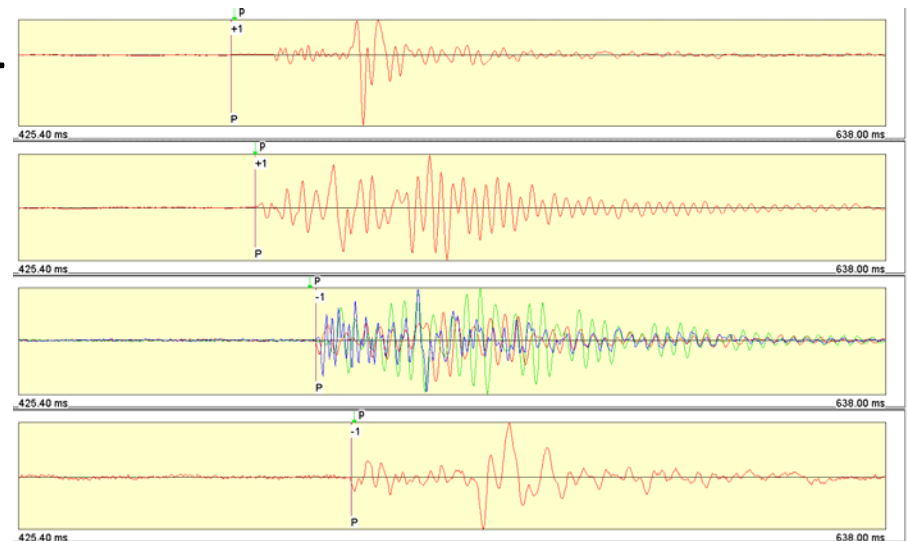
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AUTOMATIC PROCESSING

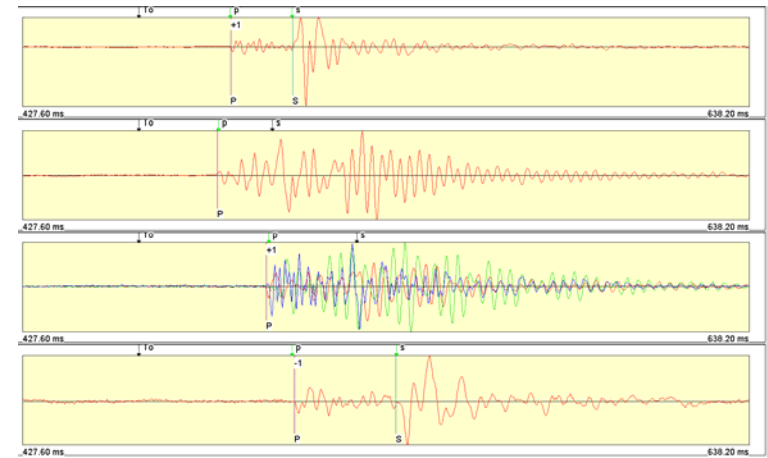
- Events are automatically processed in real time
- Software determines P-wave arrival times based on STA/LTA algorithm
 - Typically less accurate than manual processing
 - Does not pick S-wave arrivals





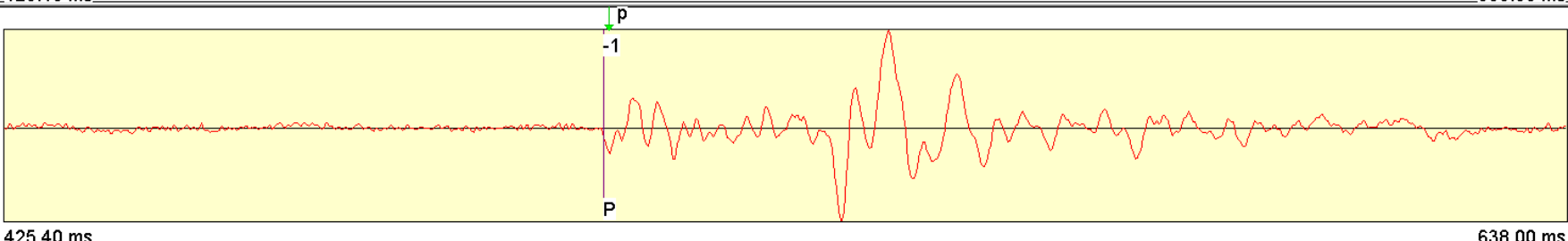
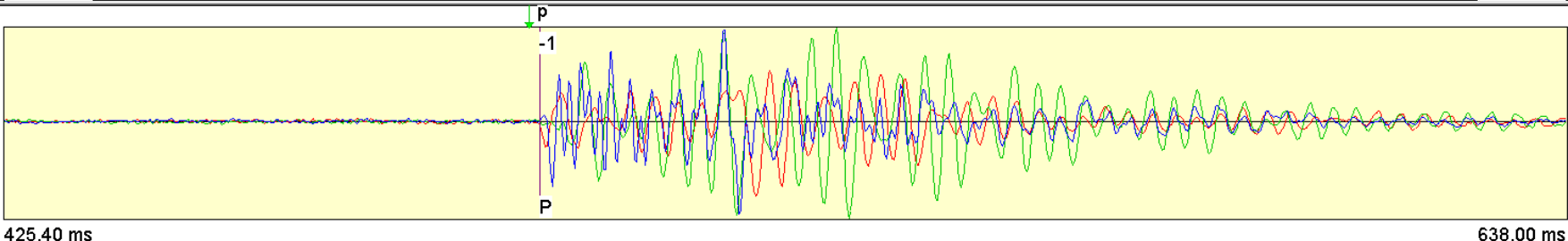
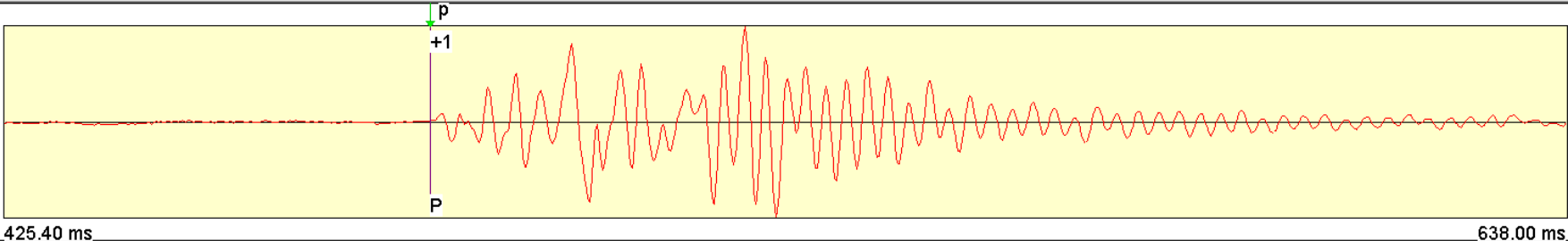
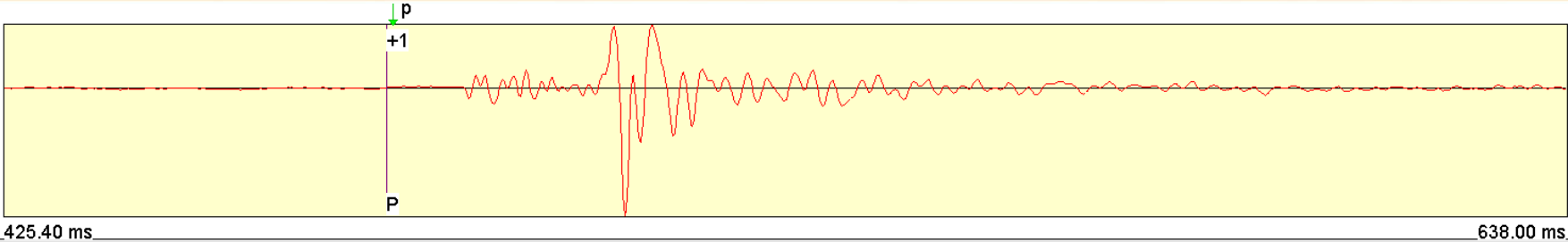
MANUAL PROCESSING

- Various event types
 - Fracture style events
 - Rock fall
 - Blasts
 - “Noise”
- Remove noise events caused by mining
- Go through each event individually to determine locations
- Process blasts



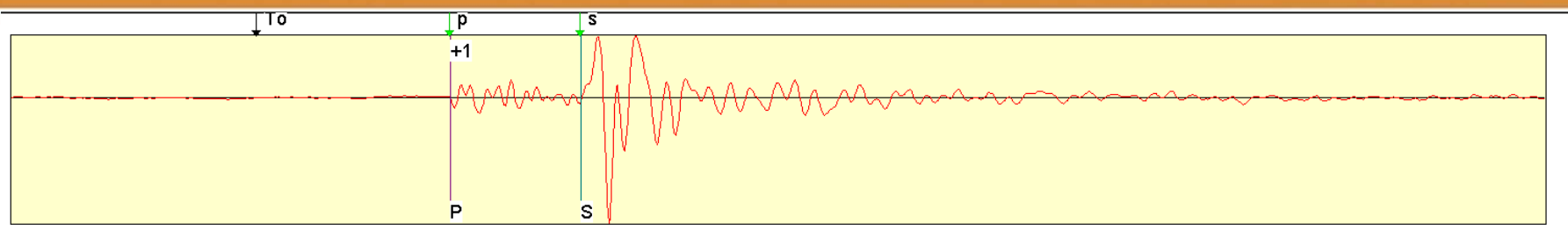


AUTOMATIC PROCESSING

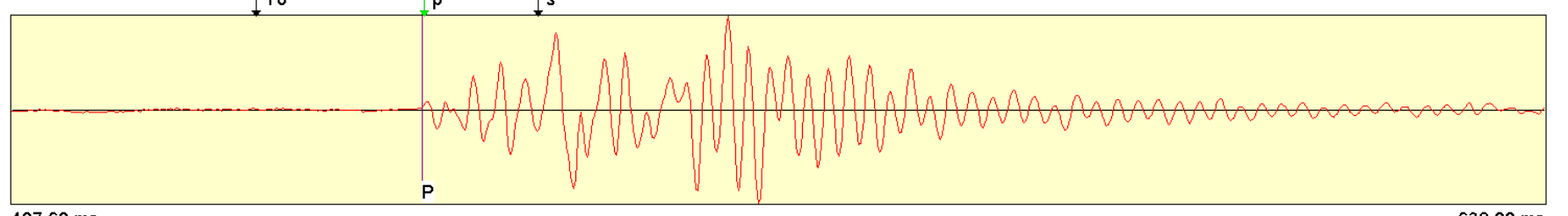




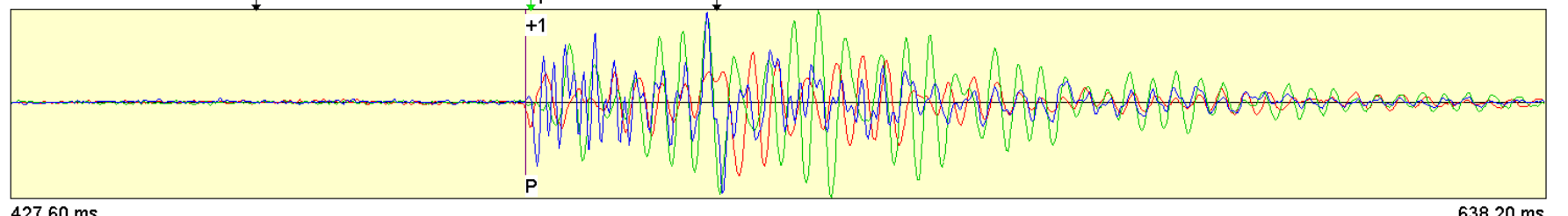
MANUAL PROCESSING



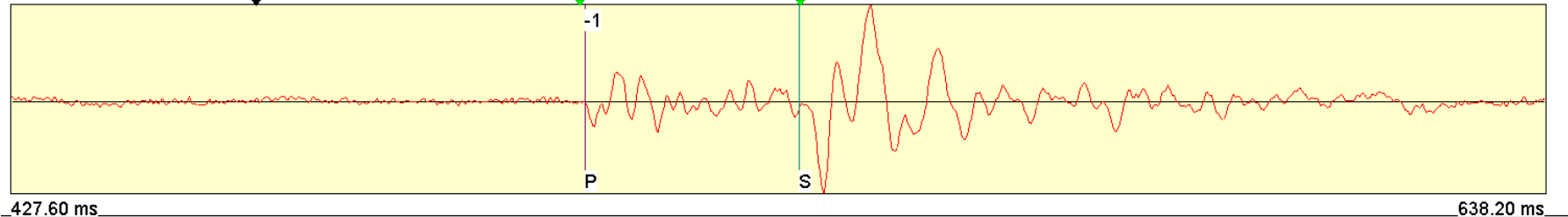
427.60 ms 638.20 ms



427.60 ms 638.20 ms



427.60 ms 638.20 ms



427.60 ms 638.20 ms





3D VISUALIZATION



- ESG SeisVis Software
 - Uses colors / shapes / sizes to differentiate magnitude and event type
- Allows visual comparison of event locations with the mine workings

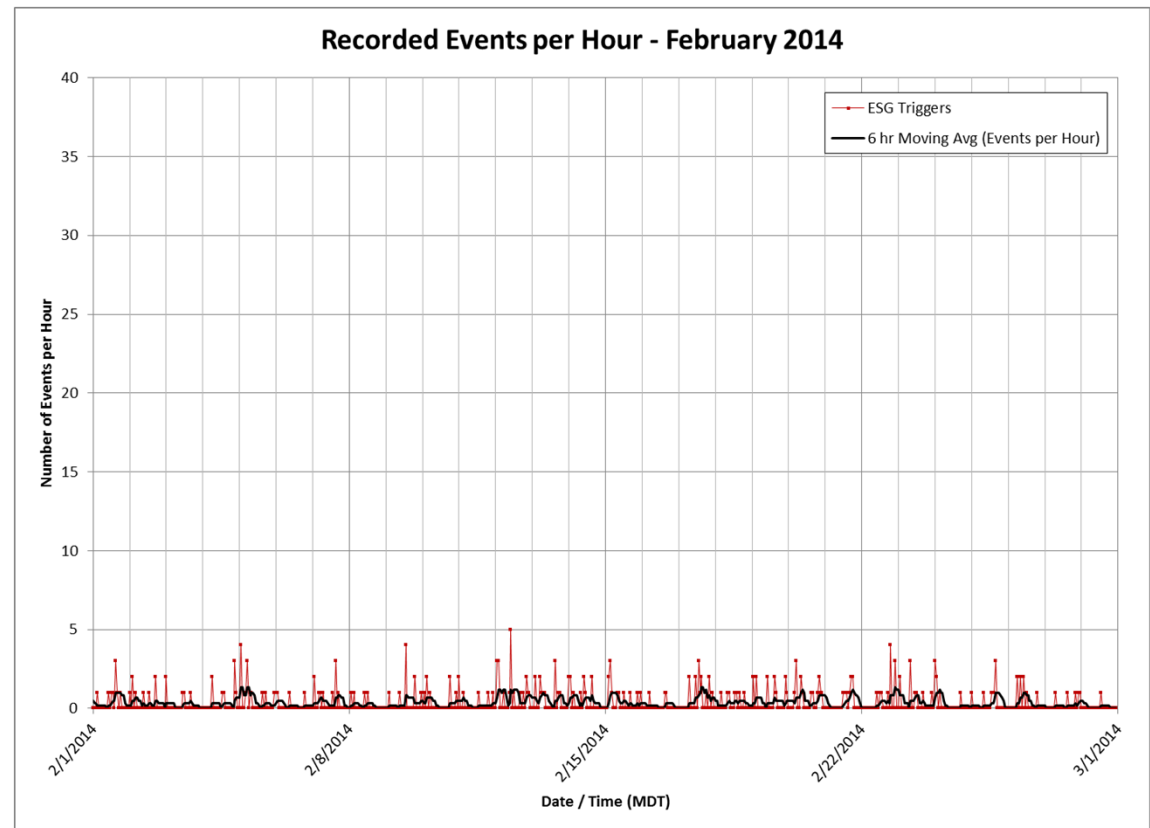
- Daily monitoring by engineering, mine, and safety departments
- Training personnel to differentiate between equipment noise and (micro)seismic events
- Remote desktop allows users to log in from anywhere with an internet connection





DATA ANALYSIS

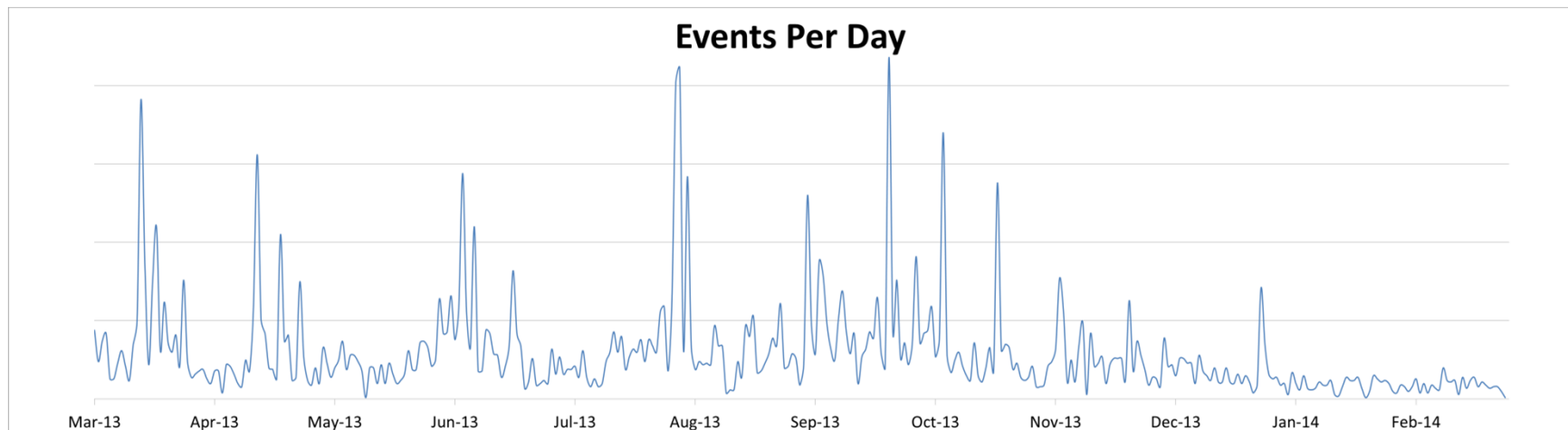
- All events are tracked in a spreadsheet
- Daily event processing
- Event frequency graphs generated regularly





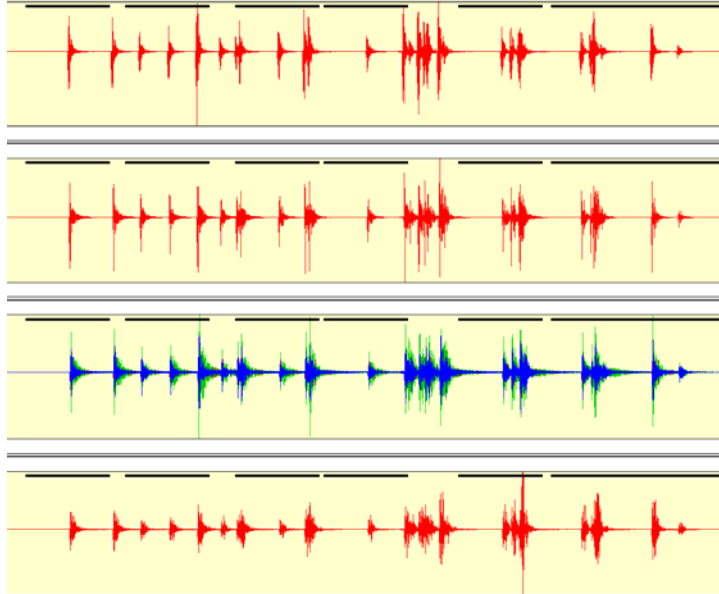
ESG GEOPHONES

- Determining background seismicity
 - What is “normal”
 - Audible noise vs measured seismicity
 - Work with geotechnical consultants to determine working and monitoring protocols



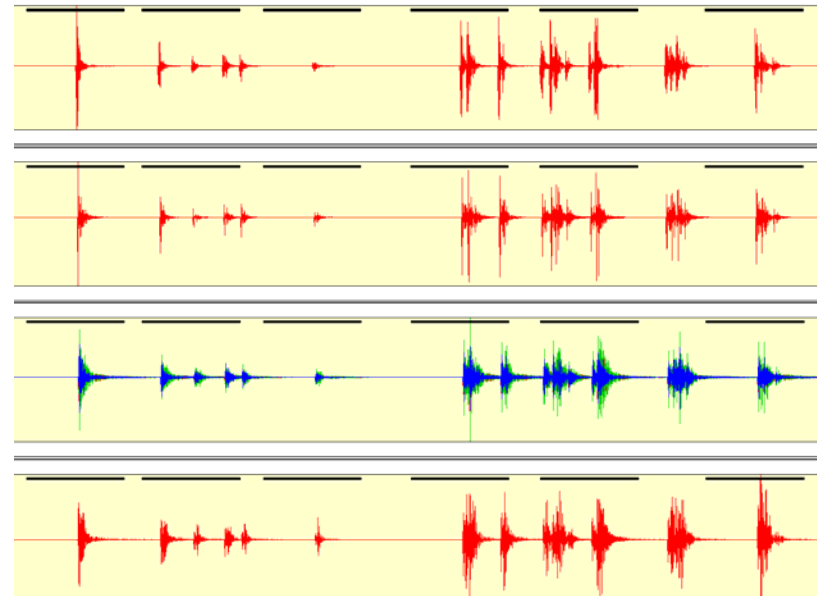


ESG GEOPHONES



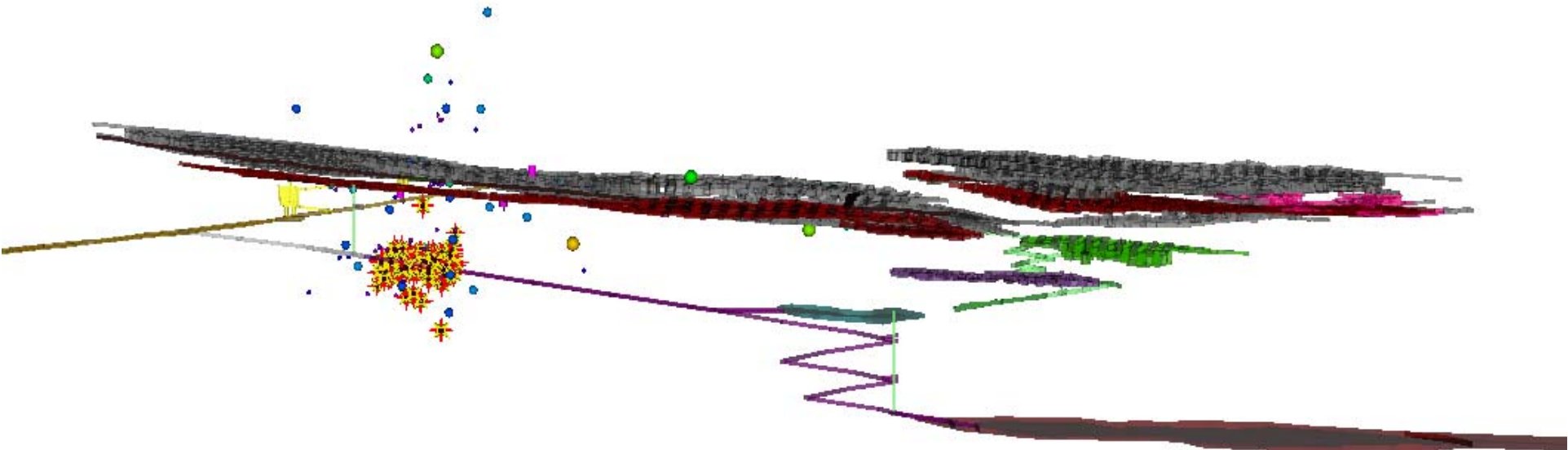
- Additional uses
 - Monitor cycle times
 - Improve practices / procedures

- System expansion
 - Modular design





SYSTEM EXPANSION





MBMG / NIOSH EXPANSION

- Improved regional seismic network
 - Worked with the MBMG to install a regional seismograph near the Troy Mine tailings facility
 - NIOSH researchers working to install a permanent station above the mine workings
 - Difficult terrain
 - Logistical issues
 - Data transmission (telemetry)





ACKNOWLEDGEMENTS

- Dr. Pete Swanson, NIOSH / OMSHR
- Mike Stickney, MBMG Earthquake Studies Office
- ESG Solutions Training Documents
- Bulletin 573, US Bureau of Mines. “Micro-seismic Method of Determining the Stability of Underground Openings” L. Obert, W.I. Duval.
- Troy Mine seismic data



QUESTIONS?

WaveVis - Event 50 => 201309.8N 200765.0E 3949.4D M= 0.2 - [TroyMine : c:\esg\Troy] seismic-pc

File Data Picking Event Options View Logging Window Help

2014-02-14/06:05:44.732 (50jb* 2C

